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STATUS OF THE RIDGE-PUSH DRIVING MECHANISM FOR PLATE TECTONICS

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Three main models that have been considered for the driving force of plate tectonics are lithospheric traction, slab pull, and ridge push.

In the lithospheric-traction model, horizontal currents that are part of convection in the lower mantle are inferred to drive the plates directly. In its most popular version, the model consists of rising equidimensional plumes that spread out below the plates and then descend as slabs near subduction zones. But the widely accepted concept of fixed hotspots, if correct, seems to be incompatible with lithospheric traction. An asthenospheric current transporting a buoyant plate would need to move as fast or faster than the plate. And it would move a sublithospheric hotspot source equally rapidly. This would carry the source along with the plate, and therefore would not lead to a hotspot track such as the Hawaiian Ridge, which is believed to be caused by faster movement of the plate than the hotspot.

In the slab-pull model, the upper-mantle part of a plate is inferred to be cooled by its proximity to the Earth's surface. This makes it shrink, become denser than the sublithospheric mantle below, and hence become gravitationally unstable. Thus, at subduction zones where plates extend down as much as 700 km into the mantle, the cool dense slab is inferred to sink because of its weight and to pull the rest of the plate in after itself. Because subduction zones are usually paired with seafloor-spreading axes, the effects of these two types of plate boundaries are difficult to separate. Probably the only example of a subduction zone that may not have a matching spreading axis is at the north end of the Philippine Plate, where subduction to the west is flanked to the east by weak or absent spreading at the Izu Volcanic Arc. But farther south on the Philippine Plate, the western subduction is matched by the Mariana Rift, and still farther south by a gap that in effect pairs the distant East Pacific Rift against subduction on the west side of the plate. The Philippine Plate moves much faster at the south than at the north, suggesting that the subduction zone, present in both places, is not the dominant cause of the plate movement. Also, some plates, such as South America, lack attachment to a subducting slab, yet their movement is reasonably fast.

In the ridge-push model, several mechanisms have been proposed. The most popular depends on the fact that thermal expansion of the plate and especially the subplate causes spreading axes to stand about 2.5 km higher than the old parts of plates. This lithodynamic head is inferred to gravitationally move the plates away from the axis. Another version of the ridge-push model involves forceful magmatic injection at spreading axes, but this version is less popular now because of the difficulty in envisioning a mechanism for the convoluted injection necessary at long offsets of spreading axes. A final version of the ridge-push model involves tidal pumping, a pulsing of the plates caused by the twice-daily passage of Earth-tidal bulges that alternately open up spreading axes to draw mineral crystals up from lower in the mantle, and then close them on incrementally enlarged plates.

The initiation of new subduction zones, such as the Aleutian, provide strong evidence that ridge push dominates over slab pull. New spreading axes probably begin as transform faults, because shear fracture requires less energy than tension, and because new spreading axes are smoothly curved. Continental spreading, even though beginning as a transform shear, may pose a special challenge to the gravitational model of ridge push, because initially no excess heat is available to elevate the plate and create a gravitational driving force. On the other hand, tidal-pumping can begin immediately after the plate is initially sheared through. Several past examples, such as the opening of Canada Basin and the rotation of Corsica and Sardinia, indicate that small plates bounded on one side by a new relatively long continental rift and on the other by a free edge at a subduction zone can almost immediately attain exceptionally high speeds